

Vapour Cloud Dynamics Induced by Evaporation

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Abstract

In this fluid dynamics video, the vapour cloud generated near evaporating free liquid surfaces is visualised by Mach-Zehnder interferometry (MZI). More precisely, for evaporating HFE-7100 (from 3M) and ambient conditions, the vapour concentration field and its dynamical behavior are observed in three simple experiments. Through these experiments, it is evidenced that the high density of the vapour cloud (compared to air) induces convective motions in the gas mixture, resulting in deviations of the concentration field from a purely diffusional behavior.

1 Introduction

Vapour concentration levels can be measured by several techniques such as infrared absorption [3] or planar laser induced fluorescence PLIF [1]. These techniques depend upon certain properties of the examined evaporating liquid, such as suitable absorption bands or fluorescent behaviour and are hence not applicable to every evaporating liquid.

Mach-Zehnder interferometry (MZI) is a very sensitive optical technique enabling the measurement of dynamically evolving refractive index fields in transparent media. This technique is already known to be suitable for precise measurements of temperature or concentration fields in liquids (e.g. [2, 4]). However, for liquids with a large vapour pressure such as HFE-7100 (from 3M), changes in vapour concentration also lead to measureable variations in optical path length, even for ambient conditions and modest integration lengths of e.g. 2 mm. While the current technique also depends upon a large

dependence of the refractive index on the vapour concentration and is hence not applicable to all liquids, it is demonstrated that MZI nevertheless could complement infrared absorption techniques and PLIF for the detailed study of vapour cloud dynamics.

2 Step by Step Explanation

The video available in the ancillary files starts with an explanation of the MZI-setup. This is followed by a first experiment where a pending drop of HFE-7100 is created and is hanging from a 2mm external diameter needle in ambient air. The vapour cloud surrounding this drop is convected downwards due to its higher density.

In the second experiment, a pending drop is created in ambient air close to a solid substrate. The vapour cloud falls down and spreads along the solid substrate. Liquid is continuously injected until a liquid bridge is formed between the needle (1mm) and the solid substrate. In this case, the iso-concentration lines in the vapour cloud adapt themselves to this new liquid shape.

In the third and final experiment, a small rectangular cuvette (of 1cm by 1cm) is filled up to some height with HFE-7100 in ambient conditions. Initially, a plastic cover prevents evaporation and a homogeneous air-vapour layer sits on top of the liquid meniscus. When the cover is suddenly removed, a fast evolution of the air-vapour layer is witnessed and it transforms into a stagnant diffusive zone which occasionally spills out some excess vapour over the edges of the cuvette. In addition, Bénard-like convection cells are visible in the liquid phase due to the free surface cooling generated by evaporation.

3 Acknowledgements

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